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Runoff and soil loss from midwestern and southeastern US silt loam soils as affected by tillage practice and soil organic matter content

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Abstract

No-till practices generally reduce runoff (RO) and soil loss (SL) by contributing to accumulations of soil organic matter (SOM) in the near-surface zone. This research was conducted to determine the effects of SOM contents on RO and SL from two highly erodible soils using crops that produce a wide range of residue, in the context of long-term tillage studies in widely separated climatic regions. Rainfall simulator plots, measuring 6.1 m $\times$ 0.9 m, were imposed on a 9-year-old corn (*Zea mays* L.) and cotton (*Gossypium hirsutum* L.) conservation tillage study at Senatobia, Mississippi, and on a similar 34-year-old corn study at Coshocton, Ohio. All RO was collected from two replications of conventional (CT) and no-till (NT) treatments following application of simulated rainfall at an intensity of 50 mm h^{-1} for 1 h. Soil samples collected in depth increments of 0–1, 1–3, 3–7.6 and 7.6–15.2 cm were characterized for SOM content, aggregate stability (AS), water dispersible clay (WDC) and particle size distribution. Bulk density (BD) samples were collected in increments of 0–3.8, 3.8–7.6, 7.6–15.2 and 15.2–30.5 cm. Overall, RO from the CT and NT treatments averaged 27.8 and 16.5 mm, respectively. SL loss from the CT treatments averaged 3.9 Mg ha^{-1} and 0 for the NT. BDs in the surface 3.8 cm averaged 1.34 Mg m^{-3} for CT and 1.26 Mg m^{-3} for NT. Correlation coefficients (r) for SOM content versus AS, WDC and BD were 0.92, −0.90 and −0.64, respectively. Regression models indicated that BD, as a single-variable, explained 87% of the variability in RO from the NT treatments. BD alone was less effective in accounting for the variability in RO from CT treatments, but contributed to a three-variable model with AS and WDC to produce an R^2 of 0.97. These results indicate that as SOM contents gradually increase in NT treatments, RO decreases due to the development of greater porosity in the near-surface zone attributable to enhanced AS at the soil surface. Thus, surface sealing tendencies are diminished which promotes an increase in infiltration rates. Published by Elsevier Science B.V.

Keywords: No-tillage; Conventional tillage; Aggregate stability; Water dispersible clay; Bulk density; Erosion; Infiltration; Soil organic matter

1. Introduction

Runoff (RO) and soil loss (SL) are problems common to most soil resources in the world, especially those with unstable aggregates in the surface horizon both from the standpoint of sustainability and offsite

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environmental damage. The environmental damage factor is becoming increasingly more important as standards for sediment and chemical pollutants in water bodies become more stringent. In many instances, the adoption of no-till (NT) practices has resulted in improvements relative to the reduction of erosion-related problems. This can be attributed, in large part, to the stabilization of the surface by increased soil organic matter (SOM) contents and the accumulation of crop residues. Some studies (Reicosky et al., 1995) have reported SOM increases of 2270 kg ha^{-1} per year in the top 15 mm of the soil surface following the introduction of NT practices. The organic matter accumulation increases water-stable aggregation in the macroaggregate (>0.25 mm) fraction (Tisdall and Oades, 1982; Franzluebbers and Arshad, 1996; Francis et al., 1999) which normally increases infiltration rates (Triplett et al., 1968; Bradford and Huang, 1994; Reicosky et al., 1995). In some soils, the organic matter-induced improvements in surface soil properties, that affect erodibility, have been shown to occur within a minimum of the first 3–4 years of the introduction of NT practices (Francis et al., 1999; Rhoton, 2000). Further, RO and SL from NT practices were reduced by a maximum of 35 and 77%, respectively, after 13 years compared to conventional-tilled (CT) systems (McGregor et al., 1999); however, substantial reductions were recorded for both parameters after only 3 years.

Although the previous studies have documented very well the effectiveness of NT practices at reducing RO and SL, essentially little effort has been made to relate these reductions to changes in soil properties that result from increased SOM contents. Thus, this study was conducted to: (1) determine the effects of SOM on RO and SL from CT and NT practices imposed on two highly erodible soils from different climatic regions, (2) characterize the influence of a wide range of SOM contents on soil properties that control infiltration rates, and (3) evaluate the effects of a CT operation on RO and SL from a long-term sod crop.

2. Materials and methods

2.1. Field

The long-term tillage experiments used in this study were established in 1988 at Senatobia, MS, on a Grenada silt loam (Soil Taxonomy—Glossic Fragiudalfs; FAO-Dystric Podzoluvisols), and in 1964 at Coshocton, OH, on a Rayne silt loam (Soil Taxonomy—Typic Hapludalfs; FAO-Haplic Luvisols). Conservation tillage yield plots ($12.2\,m \times 5.5\,m$) from a larger separate study were used to evaluate the effects of tillage on RO and SL at Senatobia. The experimental design and plot management aspects of that larger study are described in detail elsewhere (Rhoton, 2000). Briefly, the overall experiment was a randomized complete block with 14 different plots (treatments) replicated 10 times. This study used a total of eight plots, two replications of CT and NT treatments for both corn and cotton.

In terms of management, immediately prior to spring plantings, all CT plots were chisel plowed to a depth of about 20 cm and disked followed by a finishing implement (Do-All) that pulverized, mixed and firmed the seedbed. The NT plots were undisturbed except for the planting operations. All corn and cotton plots were fertilized each year based on soil test data, with a broadcast application of 13–13–13 to adjust N, P_2O_5 and K_2O levels to 50 kg ha^{-1}. The plots were later sidedressed with NH_4NO_3 at rates of 50 and 134 kg N ha^{-1} for cotton and corn, respectively. Soil pH was maintained at approximately 6.5 by liming. Fertilizer and lime applications were incorporated by tillage operations previously mentioned for CT, but left on the surface of the NT plots. Further, the NT cotton was planted into a killed wheat (*Triticum aestivum* L.) cover crop, and the NT corn was planted into a killed hairy vetch (*Vicia Villosa* Roth) cover crop.

At Coshocton, an experimental watershed that had been in NT corn for 34 years was used for the evaluation of RO and SL from conservation tillage practices. An adjacent area planted to CT corn for 14 years (since 1984) was used for comparative purposes. The agronomic practices imposed on these sites were similar to those used for corn at Senatobia, except that the CT consisted of moldboard plowing, disking and harrowing prior to planting. Additionally, cover crops were not used during the winter months.

All RO and SL data were collected from rainfall simulator plots measuring $6.01\,m \times 0.91\,m$ at Senatobia. This size was equivalent to one-half the experimental plot length times the row width. The rainfall simulator plot size of $6.01\,m \times 0.76\,m$ at Coshocton was equivalent to the plot length used at Senatobia times the row width of the NT and CT corn treatments used at that location. Simulated rainfall was applied with a multiple intensity rainfall simulator (Meyer and Harmon, 1979) at an intensity of 50 mm h^{-1} for 1 h. All RO was collected from two replications of CT and NT corn and cotton at Senatobia, and corn at Coshocton. A sub-objective of the study was to determine the effect of simulated rainfall on CT treatments immediately prior to and following seedbed preparation in the spring at Senatobia, and on first year CT (designated CT-2) following long-term sod at Coshocton. Additionally, a comparison was made of wheel track (WT) versus non-wheel track (NWT) rows in terms of RO from the NT plots at Senatobia. The NT watershed at Coshocton was not managed under such controlled traffic conditions. CT operations consisted of disking and harrowing immediately prior to applying simulated rainfall. No soil disturbance was associated with the NT treatments.

Soil samples were collected to a depth of 15.2 cm at three randomly selected points in each plot in increments of 0–1, 1–3, 3–7.6 and 7.6–15.2 cm, then composited to form one sample per depth increment per plot. Two soil cores were collected from each plot to estimate bulk density (BD) using a hydraulically driven sampler (Rhoton and McChesney, 1991). These 7.6 cm diameter cores were sectioned into increments of 0–3.8, 3.8–7.6, 7.6–15.2 and 15.2–30.5 cm.

2.2. Laboratory measurements

In the laboratory, all samples were air-dried, crushed and sieved to <2.0 mm, with the exception of the BD cores. These samples were oven-dried at 105 °C for 72 h in a forced air oven and weighed. Subsamples of the <2 mm fraction were combusted in a Leco CN-2000 C Analyzer for organic carbon contents which were converted to organic matter by multiplying by a factor of 1.72. Particle size distribution was determined by the pipette method of Day (1965) after the samples were treated with 30% H_2O_2, and dispersed overnight in Na–hexametaphosphate. Water dispersible clay (WDC) contents were determined by the same pipette method, but the samples were not treated with H_2O_2, and distilled water was used as the dispersant. Aggregate stability (AS) was determined by wet sieving 1–2 mm diameter soil aggregates on a 60 mesh sieve for 5 min by the procedure of Kemper (1965), with the exception that these samples were not pre-wetted.

2.3. Statistical

Statistical analyses were performed using the GLM, CORR and REG procedures of SAS Version 7 (SAS Institute, 1997) to assess differences in treatment means, determine correlation coefficients and derive linear regression models.

3. Results and discussion

3.1. Soil properties

The most obvious difference in the soil characterization data for the various plots (Table 1) is the greater SOM concentrations in the NT. In most cases, the NT treatments contained statistically significant ($p \leq 0.05$) greater amounts of SOM in the surface 3 cm relative to CT regardless of crop or study location. The NT plots at Senatobia had more than twice the SOM concentrations of the CT at the 0–1 cm depth, with treatment differences being greatest for corn. The NT corn also had substantially more SOM than CT treatments at the 1–3 cm depth, but from 3 to 15 cm NT contained only slightly more SOM. NT cotton also contained more SOM at 1–3 cm relative to CT, but the differences between treatments were much less compared to the same treatments for corn (i.e., 37% versus 57% for corn). SOM concentrations were essentially the same for CT and NT cotton from 3 to 15 cm. Additionally, the SOM concentrations in the CT corn and cotton were comparable below 3 cm; however, corn had slightly more SOM in the surface 3 cm. The NT plots at Coshocton contained nearly five times the SOM concentration of the CT-1 plots between 0 and 1 cm, and four times more SOM at 3–7.6 cm. For the two lower depths, NT contained approximately 3.2 and 1.5 times more SOM than the CT-1 treatment. These results that show greater SOM concentrations in the surface of NT relative to CT treatments are consistent with those of other researchers (Rhoton et al., 1993; Edwards et al., 1992; Ismail et al., 1994; Lal et al., 1994). Soil samples from the Coshocton CT-2 plots located on the long-term sod

Table 1
Selected properties of the soil samples collected from the rainfall simulator plots at Senatobia, MS, and Coshocton, OH

Location	Crop	Tillage treatment	Sample depth (cm)	Organic matter ($g\ kg^{-1}$)	Particle size distribution ($g\ kg^{-1}$)			Water dispersible clay (%)	Aggregate stability (%)
					Sand	Silt	Clay		
Senatobia, MS	Cotton	CT	0–1	18.0 bc[a]	19 ab	812 ab	169 bc	4.8 b	26.8 bc
			1–3	13.9 cd	15 b	788 b	197 b	6.0 a	14.3 d
			3–7.6	13.3 cde	16 ab	788 b	196 b	6.0 a	16.6 cd
			7.6–15.2	7.5 e	9 b	735 c	256 a	6.8 a	26.4 bc
		NT	0–1	37.4 a	18 ab	843 a	139 c	3.2 c	55.9 a
			1–3	22.1 b	19 ab	850 a	131 c	3.8 c	33.8 b
			3–7.6	13.7 cd	34 a	828 ab	138 c	3.6 c	31.1 b
			7.6–15.2	7.9 de	12 b	790 b	198 b	6.3 a	34.5 b
	Corn	CT	0–1	20.4 c	12 ab	818 ab	170 abc	4.7 bc	35.3 b
			1–3	15.6 cd	12 ab	813 ab	175 abc	5.6 ab	23.6 b
			3–7.6	13.2 de	12 ab	800 ab	188 abc	6.0 ab	24.2 b
			7.6–15.2	6.9 f	8 b	774 b	218 a	6.7 a	21.8 b
		NT	0–1	49.8 a	19 a	855 a	126 c	2.5 d	66.5 a
			1–3	30.1 b	14 ab	844 a	142 bc	3.6 cd	53.9 a
			3–7.6	17.4 cd	15 ab	846 a	139 bc	3.7 cd	36.7 b
			7.6–15.2	9.5 ef	10 b	796 ab	194 ab	6.0 ab	32.5 b
Coshocton, OH	Corn	CT-1[b]	0–1	20.8 ef	162 c	644 bc	194 d	11.6 ab	30.5 d
			1–3	20.6 ef	163 c	643 c	194 d	12.3 a	32.5 d
			3–7.6	21.4 ef	155 c	646 abc	199 cd	10.8 bc	33.1 d
			7.6–15.2	19.5 ef	158 c	647 abc	195 d	10.8 bc	30.8 d
		NT	0–1	98.5 a	217 a	546 f	237 ab	6.2 d	87.5 a
			1–3	83.6 b	203 a	555 f	242 a	6.5 d	81.9 ab
			3–7.6	67.5 c	187 b	590 e	222 ab	6.8 d	77.8 b
			7.6–15.2	28.6 d	164 c	618 d	218 ab	10.6 bc	53.9 c
		CT-2[c]	0–1	24.8 def	123 d	658 abc	219 bc	10.4 c	55.9 c
			1–3	25.3 def	111 de	667 a	222 ab	10.6 bc	55.2 c
			3–7.6	25.5 def	120 d	661 abc	219 bc	7.0 d	54.0 c
			7.6–15.2	23.4 def	103 e	664 ab	233 ab	7.2 d	56.7 c

[a] Means followed by the same letter for a given crop and location are not statistically different at $p \leq 0.05$ based on Duncan's new multiple range test.
[b] This site had been conventionally tilled for 14 consecutive years.
[c] Long-term sod crop that had been freshly tilled.

generally contained significantly ($p \leq 0.05$) less sand and more clay than the CT-1 plots. Silt contents were statistically similar, although slightly higher in the CT-2. This suggests that the clay and silt fractions have been preferentially eroded from the older CT-1 site resulting in an increase in sand contents. The CT-2 samples also contained slightly higher SOM concentrations than CT-1, with a weighted average for 0–15.2 cm depth of 24.4 $g\ kg^{-1}$ versus 20.3 $g\ kg^{-1}$. These greater SOM concentrations in CT-2 undoubtedly contributed to the lower WDC contents and higher AS levels observed relative to CT-1. On the basis of these results, the CT-2 should be less erodible than the CT-1 soils.

The impact of SOM concentration increases under NT is evidenced by the differences in WDC and AS for the two tillage treatments (Table 1). These two soil properties, which strongly influence erodibility and infiltration rates, and thus RO, are inversely related. Specifically, as WDC increases (indicating an unstable soil material), a decrease is normally observed in AS. In practically all cases, WDC is significantly ($p \leq 0.05$) less for the NT relative to the CT soils. Conversely, AS was significantly ($p \leq 0.05$) greater in the NT relative to the CT plots. These relationships hold regardless of sampling depth with the exception of WDC contents for CT and NT at the 7.6–15.2 cm depth. The particle size data (Table 1) indicate that the Senatobia soils contained approximately 20–25% more silt and 15–20% less sand than the Coshocton soils. Clay contents were substantially greater at Coshocton, especially in the NT plots. The significantly $(p \leq 0.05)$ higher clay contents in the NT relative to CT plots at Coshocton is the opposite of NT soils at Senatobia where both cotton and corn plots trended towards less clay than CT. Erosion of the CT plots at Senatobia primarily removed silt from the surface horizons and resulted in clay enrichment as subsurface materials higher in clay were exposed at the surface by cultivation. The higher clay contents in NT soils at Coshocton suggest that the NT watershed may have been more eroded than the adjacent CT area prior to initiation of the study.

BD measurements (Table 2) at Senatobia did not show any significant $(p \leq 0.05)$ differences between CT and NT for either crop. The 0.18 Mg m^{-3} lower value in the WT row of the NT corn is questionable. The CT and NWT row of NT cotton and corn had similar densities below 3.8 cm. At the Coshocton location, the NT plots had lower BD values at all depths than the re-consolidated CT plots, but there were few significant $(p \leq 0.05)$ differences. The relationships between SOM concentrations, AS, WDC and BD for these soils are shown in Figs. 1–4. AS versus SOM concentrations (Fig. 1) had an r-value of 0.92 $(p \leq 0.01)$, using all samples from both locations. Obviously, AS of these samples is strongly related to SOM contents. Conversely, SOM contents and WDC were poorly correlated with an r-value of -0.07; however, when the data were separated on the basis of location (Fig. 2), the r-values were improved to -0.96 $(p \leq 0.01)$ at Coshocton, and -0.83 $(p \leq 0.01)$ at Senatobia. In both cases, the results indicate that WDC decreases approximately 50% as the SOM concentrations increase within the range of these samples. A similar relationship existed for AS versus WDC (Fig. 3). Once the data were separated by site, the r-values were -0.94 $(p \leq 0.01)$ at Coshocton and -0.73 $(p \leq 0.01)$ at Senatobia. The two separate curves for WDC versus SOM concentrations and AS suggest that a combination of inorganic cementing agents and SOM are more influential in aggregate stabilization than SOM alone since the higher SOM contents at Coshocton did not contribute to lower

Table 2
Bulk densities determined for core samples collected from the CT and NT rainfall simulator plots

Location	Crop	Sample depth (cm)	Bulk density (Mg m^{-3})	
			CT	NT
Senatobia, MS	Cotton	0–3.8	1.46 bc[a]	1.35 c (1.42 c)[b]
		3.8–7.6	1.41 c	1.45 bc (1.64 a)
		7.6–15.2	1.44 c	1.47 bc (1.57 ab)
		15.2–30.5	1.45 bc	1.43 c (1.44 c)
	Corn	0–3.8	1.29 cd	1.28 d (1.10 e)
		3.8–7.6	1.42 abc	1.42 abc (1.53 a)
		7.6–15.2	1.38 bcd	1.45 ab (1.55 a)
		15.2–30.5	1.43 abc	1.45 ab (1.43 abc)
Coshocton, OH	Corn	0–3.8	1.26 cde (1.38 bcd)[c]	1.15 e
		3.8–7.6	1.47 abc (1.39 abcd)	1.22 de
		7.6–15.2	1.47 abc (1.49 ab)	1.43 abcd
		15.2–30.5	1.61 a (1.43 abcd)	1.51 ab

[a] Means followed by the same letter for a given crop and location are not statistically different at $p \leq 0.05$ based on Duncan's new multiple range test.

[b] Bulk density values at Senatobia, MS, are from the NWT rows. Values in parentheses are for WT rows. NT treatments at Coshocton, OH, did not contain this component.

[c] The CT BDs at Coshocton, OH, are for the 14 years treatment, with the freshly tilled treatment in parentheses.

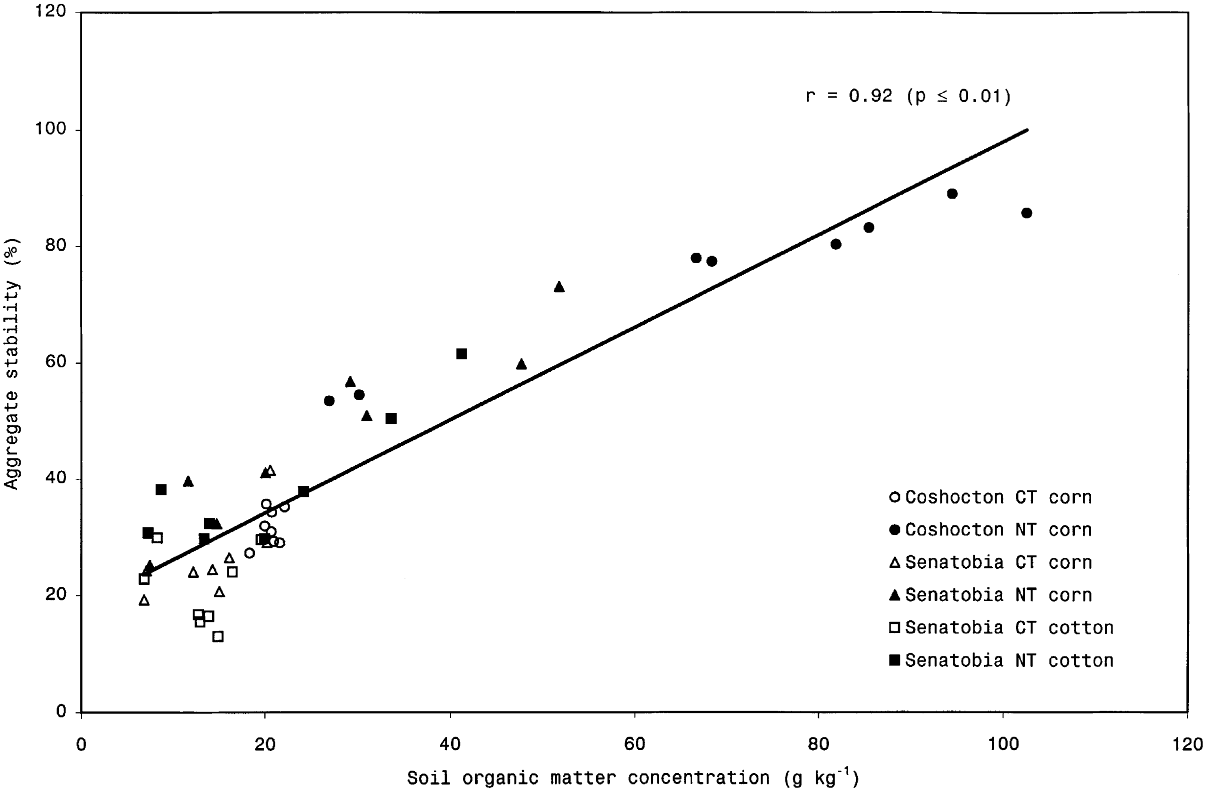

Fig. 1. Correlation coefficient (r) determined for AS as a function of SOM concentrations at the two study locations.

absolute values for WDC. Presumably, the Senatobia soils contained higher concentrations of inorganic cementing agents (Fe, Al, Si) relative to Coshocton soils. Particle size distributions between the two locations do not appear to differ enough to create such large differences in WDC and the aggregation indices (total clay/WDC) were similar for the two soils. SOM concentration versus BD at 0–3.8 cm (Fig. 4) had an r-value of -0.64 ($p \leq 0.05$) indicating a substantial decrease in BD at the higher SOM concentrations.

3.2. Runoff and soil loss

RO ranged from 6.9 mm for NT corn at Coshocton to 35.1 mm for NT cotton (WT row) at Senatobia (Table 3). Statistically significant ($p \leq 0.05$) less RO occurred on the NT treatments relative to CT at Coshocton. SL ranged from 0 for all NT treatments to 5.6 Mg ha^{-1} for CT cotton at Senatobia. The CT cotton and corn plots at Senatobia were evaluated in a freshly tilled, and untilled condition since the previous growing season to demonstrate the differences that exist in these surfaces with time since seedbed preparation. The freshly tilled cotton plots had 22% more RO and 96% more SL than the untilled plots. RO and SL from the tilled CT corn plots were 16 and 89% greater than the untilled plots, respectively. The NT treatments were sampled as NWT and WT row components at Senatobia to determine the effects of traffic on RO. The NWT row corn had 45% less RO than the WT rows and NWT cotton produced 21% less RO than the WT rows. These differences are explained by the generally greater BD of WT rows (Table 2).

The tilled CT and NWT row of the NT were considered most representative for comparing CT and NT treatments. In this regard, NT cotton and corn at Senatobia had 17 and 26% less RO, respectively,

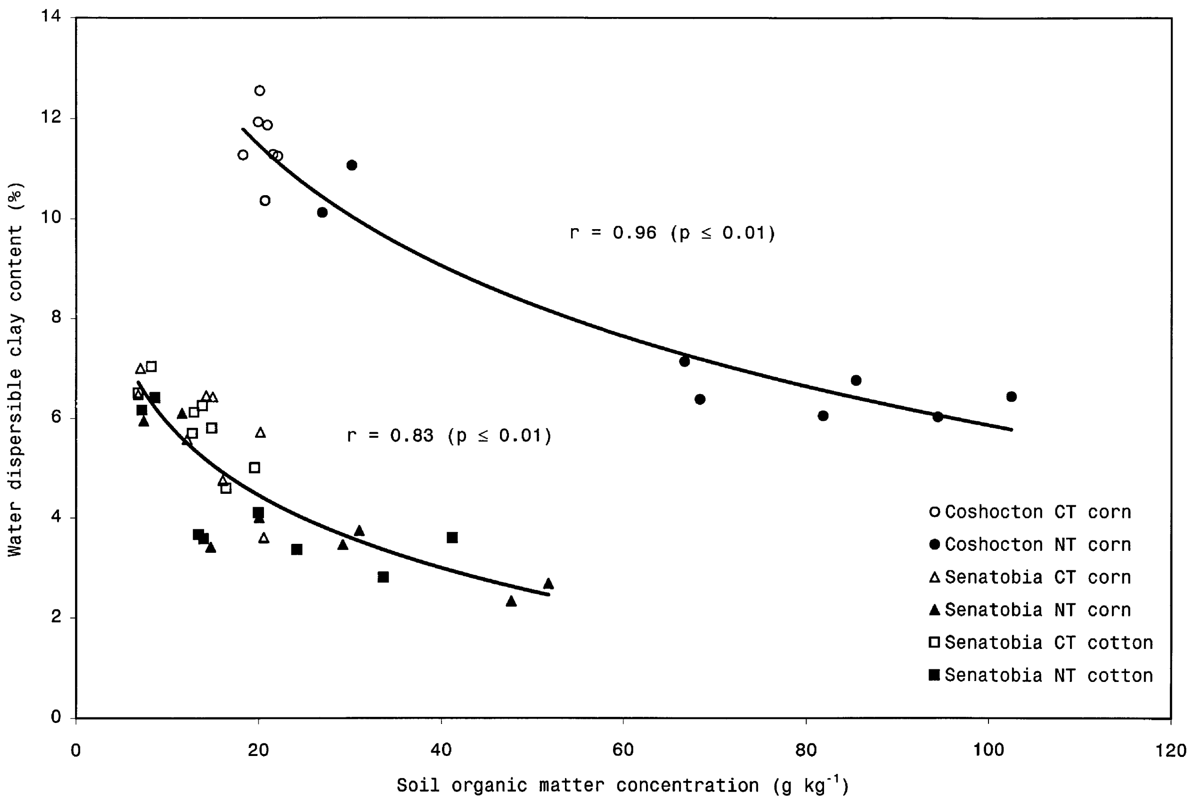

Fig. 2. The influence of SOM concentrations on WDC contents as a function of study location.

than their CT treatments. Relative to crop, corn consistently produced lower RO than cotton. The average difference was 36% considering all data sources. SL from the CT corn at Senatobia averaged less than 50% of that eroded from the cotton plots, 2.7 Mg ha^{-1} versus 5.6 Mg ha^{-1}. No measurable SL was recorded for either NT cotton or corn. These reductions in RO undoubtedly existed at some time interval much

Table 3
Total RO and SL measured after application of simulated rainfall at 50 mm h^{-1} to CT and NT plots for 1 h

Location	Crop	CT				NT			
		RO (mm)		SL (Mg ha^{-1})		RO (mm)		SL (Mg ha^{-1})	
		Tilled	Untilled	Tilled	Untilled	NWT[a]	WT[b]	NWT	WT
Senatobia, MS	Cotton	33.4 a[c]	26.0 a	5.6 a	0.2 b	27.7 a	35.1 a	0	0
	Corn	20.1 a	17.0 a	2.7 a	0.3 a	14.8 a	26.8 a	0	0
Coshocton, OH	Corn	29.8 a	NA[d]	3.5 a	NA	6.9 b	NA	0	0
	Sod[e]	23.3 a	NA	2.3 a	NA	NA	NA	NA	NA

[a] Non-wheel track row.
[b] Wheel track row.
[c] Means followed by the same letter for a given crop and location are not statistically different at $p \leq 0.05$ based on Duncan's new multiple range test.
[d] Not applicable.
[e] Long-term sod adjacent to CT corn that was tilled by moldboard plow, disk and harrow immediately prior to rainfall application.

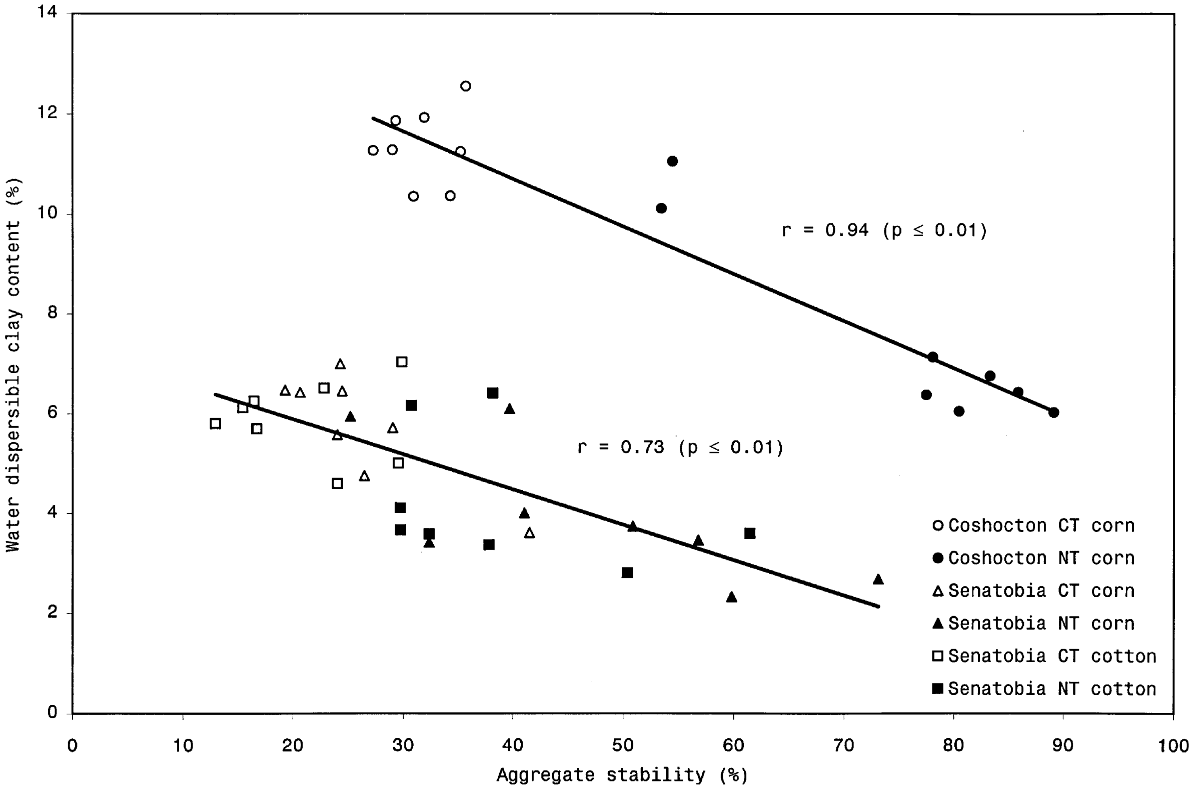

Fig. 3. The relationship between WDC concentrations and AS.

shorter than the 9-year associated with this study. Previous research at Senatobia (Rhoton, 2000) has shown that NT practices create statistically significant changes in surface soil properties within 4 years that are instrumental in reducing RO and SL. There were no untilled components for CT, or WT row for NT treatments at Coshocton; however, there was a difference of 85% between RO amounts collected from the two replicated NT plots, 11.7 Mg ha^{-1} versus 1.9 Mg ha^{-1}. This greater RO was probably due to a higher BD associated with a WT created during planting operations. BD in the surface of the 7.6 cm of the high RO plot was 1.24 Mg m^{-3} compared to 1.14 Mg m^{-3} for the low RO plot. Although RO was recorded on these relatively small plots, the long-term record indicates that essentially no RO occurs on a whole watershed basis (Shipitalo et al., 2000). Regardless, the NT corn at Coshocton had 77% less RO than the CT corn, and no SL compared to an average of 3.5 Mg ha^{-1} for CT. The CT plots that had been in sod yielded 22% less RO and 34% less SL than the long-term CT corn counterpart. This relatively small difference in RO and SL indicates that the beneficial aspects of sod relative to erosion control can be lost within a short-time period once CT practices are re-introduced. Similar observations were made by Gilley and Doran (1998) after evaluating the effects of cultivation on sod formed in association with the conservation reserve program. Additionally, Stockfisch et al. (1999) indicated that a single plowing completely eliminated the stratification and accumulation of organic matter on a 20-year-old conservation tillage study in Germany.

3.3. Regression analysis

Regression models were derived using RO as the dependent variable and SOM concentration, AS, WDC, BD and total clay (TC) as independent variables (Table 4). These models were determined for

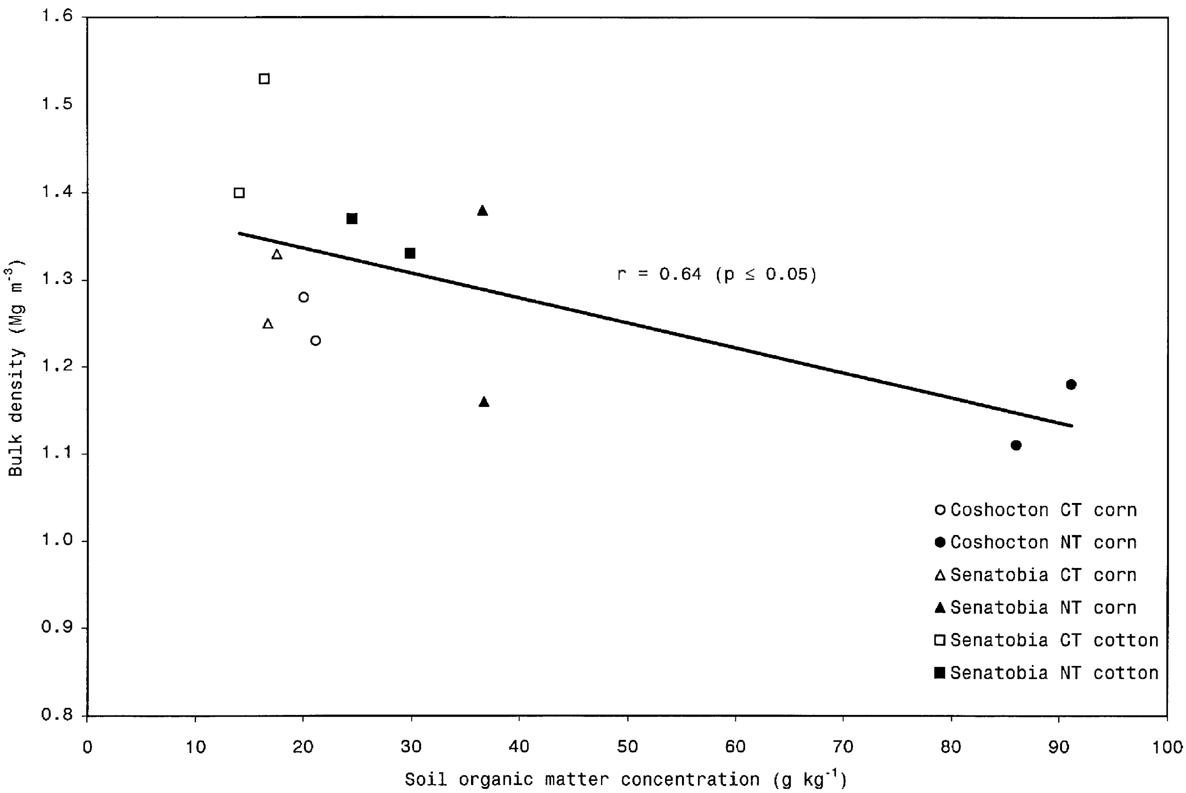

Fig. 4. The effects of SOM concentrations on the BD in the surface 3.8 cm of the CT and NT plots.

Table 4
Multiple linear regression models relating RO to SOM concentrations, AS, WDC, TC and BD as a function of tillage treatment

Tillage treatment	Soil depth (cm)	N	Dependent variable	Independent variables in model	Regression model	r^2 or R^2
CT	0–1	6	RO	1	51.83 − 0.78AS	0.51
				2	−57.18 + 1.48WDC + 55.72BD	0.75
				3	−26.03 − 0.53AS + 1.18WDC + 46.32BD	0.96**
	1–3	6	RO	1	−10.98 + 28.97BD	0.26
				2	30.93 − 0.96AS + 2.46WDC	0.82*
				3	−20.79 − 0.64AS + 2.44WDC + 33.08BD	0.97**
NT	0–1	6	RO	1	−91.42 + 85.98BD	0.87*
				2	68.31 − 1.11AS + 1.55TC	0.91*
				3	54.65 + 1.24AS − 13.14WDC + 6.04TC	0.97**
	1–3	6	RO	1	−91.42 + 85.98BD	0.87*
				2	−64.12 − 0.11AS + 69.18BD	0.88*
				3	−115.16 + 0.78SOM − 3.70TC + 127.31BD	0.90*

* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.

CT and NT treatments separately at sampling depths of 0–1 and 1–3 cm in each case. These two depths, especially the 0–1 cm, were considered the most influential in terms of effect on RO and SL. SL data, however, were not included in these analyses since none were recorded for the NT treatments.

RO from the CT plots was best explained by AS as a single-variable model, when the soil properties of the 0–1 cm depth were taken into consideration. This parameter accounted for 51% of the variability. The best two-variable model at this soil depth contained WDC and BD, and explained 75% of the variability. This value was increased to 97% with the addition of AS to the WDC and BD variables as the best three-variable model. At the sample depth of 1–3 cm, BD was the soil property that accounted for the greatest amount of variability in RO from the CT plots in the single-variable model, but it explained only 29% of the variation. This improved to 82% in Model 2 which consisted of AS and WDC. The addition of BD to these two variables gave the best three-variable model which explained 97% of the variation in RO. These results indicate that AS, WDC and BD accounted for approximately 97% of the variability in RO from the CT treatments.

Relative to NT treatments, BD was the single most important soil property at the 0–1 cm sampling depth, explaining 87% of the variability in RO. The best two-variable model, which contained AS and TC, accounted for only an additional 4%, or 91% of the variability in RO. This increased to 97% for the best three-variable model which contained AS, WDC and TC. At the 1–3 cm sampling depth, BD again comprised the best single-variable model, accounting for 87% of the variability. There was essentially little improvement in R^2 afforded by the two- and three-variable models. In fact, BD in the surface 3 cm could be used as a single-variable to explain approximately 87% of the variability in RO from NT treatments imposed on these soils.

The greater importance of BD in the NT regression models relative to CT is probably due to the higher SOM contents in the NT treatments. In this case, BD is essentially a measure of surface porosity which is stabilized by the higher SOM contents to the extent that AS, WDC, SOM and TC are relatively unimportant on an individual basis. Consequently, infiltration is greater for the NT treatments. Conversely, the surface porosity component of the CT treatments is lower and less stable relative to the NT due to less SOM, thus the soil surface seals faster and more RO occurs which is more a function of AS and WDC than BD.

4. Conclusions

The implementation of NT practices on the soils evaluated in this study created conditions at the soil surface which led to substantial reductions in RO and SL. At Senatobia, MS, RO measurements conducted after 9 years indicated an average reduction of 17% on NT cotton and 26% on NT corn relative to their CT treatments. RO from the 34-year-old NT corn treatments at Coshocton, OH, were 77% lower compared to the CT component.

The reductions in RO and the lack of any measurable SL from the NT treatments are attributed to increased SOM contents and their effect on other soil properties that influence infiltration and surface sealing such as AS, WDC and BD. In this regard, regression models indicated that BD was the most important of these soil properties in terms of accounting for variability in RO from the NT treatments. The fact that BD explains less variability in RO from CT relative to NT plots suggests that the CT soils are primarily composed of relatively unstable microaggregates (<0.25 mm) that breakdown rapidly, creating surface seals that reduce infiltration. Thus, at the lower SOM contents, WDC contents and AS are better estimators of RO since they control surface sealing under CT conditions. Conversely, at the higher SOM contents more stable macroaggregates (>0.25 mm) predominate that contribute to greater surface porosity and infiltration. This enhanced AS due to higher SOM contents effectively determines RO rates.

The soil data from Senatobia, MS, indicate that RO and SL from CT treatments can vary considerably depending on time since last tillage, and the differences in SOM contents produced by a specific crop. Likewise, WT and NWT rows should be clearly defined when evaluating RO and SL from NT practices. Additionally, the data from Coshocton, OH, show that the beneficial aspects of long-term sod can be severely impacted, in terms of increased RO and erosion, immediately following only one seedbed preparation by CT. Undoubtedly, the enhanced RO and erosion is related to the disruption of soil structure, and can be expected to increase as the higher levels of SOM associated with the sod crop gradually decline.

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